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Whistler-Mode Propagation Data No. 2

by
D. L. Carpenter and G. B. Carpenter

January 1963

Technical Report No. 1112-1

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National Science Foundation Grant NSF G-17037
Office of Naval Research Contract Nonr-225(27)
Air Force Contract AF49(638)-1060

RADIOSCIENCE LABORATORY
STANFORD ELECTRONICS LABORATORIES
STANFORD UNIVERSITY · STANFORD, CALIFORNIA

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Radioscience Laboratory
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ABSTRACT

Routine data on whistler dispersion and on whistler-mode echoes from VLF-pulse transmissions are tabulated. The whistler data were obtained at Stanford, California (1 July to 31 December 1961), at Seattle, Washington (1 July to 31 October 1961 and 1 to 31 December 1961), and at Logan, Utah (1 to 30 November 1961). Data are sampled on a daily basis. The times of occurrence, values of dispersion at 5 kc, and the frequency and travel time at the whistler nose are tabulated.

Data on whistler-mode echoes from VLF station NPG (Jim Creek, Washington, 18.6 kc) were obtained at Stanford, California. Hourly values of two-hop echo travel time, activity index, and quality factor for the period 1 November to 31 December 1961 are tabulated.

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TABLES

ACKNOWLEDGMENT

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I. INTRODUCTION

This report provides routine data on whistler dispersion and on whistler-mode echoes from VLF-pulse transmissions. It is the second in a series of reports on whistler-mode propagation data, the first report being "Data Summary: Whistler-Mode Propagation" [Ref. 1].

A description of the analysis facilities developed for VLF research and additional information on VLF studies at Stanford are contained in Refs. 2-6.

Chapter II presents tabulated results of whistler measurements at Stanford, California and Seattle, Washington during the last 6 months of 1961. (Data from Logan, Utah are given for the month of November in place of the corresponding Seattle data, which were of low quality because of interference from another experiment.) These results include dispersion measurements at 5 kc and values of frequency and travel time at the whistler nose. The tables are preceded by a brief description of the scaling methods employed.

Two-hop echo travel times for pulse transmissions at 18.6 kc are tabulated in Chapter III. The observations were made at Stanford during the period 1 November to 31 December 1961. The tables are preceded by a brief description of the data analysis and the scaling procedures employed.

II. WHISTLER RESULTS

The data tabulated in this chapter are a representative sample of recordings made at Stanford (43.7° N geomagnetic) and Seattle (53.6° N geomagnetic) for the recording period July through December 1961, except that for the month of November data from Logan, Utah (49.4° N geomagnetic) were used in place of data from Seattle.

The times of occurrence of events listed in the tables are approximate. The times given are based on aural data sheets, which are typically accurate to within several seconds.

A. WHISTLER DISPERSION AT 5 kc (TABLE 1)

1. Definition of D_5

Dispersion at 5 kc (D_5) is defined as

$$D_5 = t_5 \sqrt{5000} \ \mathrm{sec}^{1/2}$$

where t_5 is a measure of the travel time from the originating lightning flash to the appearance of the whistler energy at 5 kc, and is weighted according to the intensity of the various traces of the whistler (see below).

2. Determination of t_5

In the scaling procedure [Ref. 7], the whistler energy at 5 kc is divided into three relative intensity levels. (The records used are Sonagrams produced by a Kay Electric Sonagraph.) The travel times of the leading and trailing edges of the various traces are scaled, then weighted according to relative trace intensity and averaged to form the weighted travel time t_5. In the case of short (one-hop) whistlers, measurements are made from a point 30 msec preceding the causative atmospheric. This interval accounts approximately for the propagation time of the energy traveling in the earth-ionosphere waveguide from the originating flash to the receiver.

3. Selection of Data for Analysis

For each UT recording day at a station the Sonagraph operator obtains spectrograms representing a single 2-min run near local midnight. One to three whistlers are analyzed. The run selected is usually the

one indicated in the aural data sheets as containing the loudest whistlers. When it is possible to identify the causative atmospheric of one or more of the whistlers representing a station-day, the best defined of these is scaled for dispersion at 5 kc. Thus, the absence of an entry in Table 1 does not necessarily mean that whistlers were not observed on the day in question.

4. Error in D_5

The 90-percent range of error in D_5 for typical cases is estimated to be ±6 percent [Ref. 1].

B. FREQUENCY AND TRAVEL TIME AT THE WHISTLER NOSE (TABLE 2)

1. Direct Observations of f_n and t_n

When the frequency and travel time at the whistler nose are scaled directly on the records, the results are recorded in Table 2 and are marked by an x in the column labeled "Actual Nose." Most of the actual noses were recorded at Seattle and exhibit values of f_n in the range 4-16 kc.

2. Extension Methods of Obtaining f_n and t_n [Ref. 8]

Extension methods are used when the whistler trace of interest does not exhibit an observable nose on the spectrographic records. Travel-time measurements t_u and t_ℓ are made at two frequencies, f_u and f_ℓ. The upper frequency f_u is chosen to be near the highest observable frequency of the whistler trace. The ratio f_ℓ/f_u is typically 0.5. On the basis of these two independent measurements and a simplified form of the dispersion law of whistlers derived by R. L. Smith [Ref. 9], the values of f_n and t_n for the trace are calculated.

3. Selection of Data for Analysis

The whistlers scaled for (f_n, t_n) are usually taken from the data scaled for dispersion at 5 kc. The whistler traces to which extension methods are applied must exhibit well defined, continuous edges over the range f_u to f_ℓ, and it is desirable that the ratio f_u/f_n be greater than 0.3. In the case of multicomponent whistlers, more than one trace is scaled whenever possible.

4. The 90-Percent Errors in f_n and t_n

Experimental errors are listed in Table 2. In the case of an actual nose, the uncertainty in f_n is independent of that in t_n. In all other cases, the two uncertainties are not independent, and the values given should be regarded as the coordinates of the two end-points of an error "locus" extending from the observed value of (f_n, t_n) [Ref. 10]. The minus/plus error column for t_n is to be associated with the plus/minus error column for f_n in these cases.

TABLE 1a. WHISTLER DISPERSION AT 5.0 kc

Station: Stanford (43.7° N Geomagnetic)

Date	July 1961		August 1961		September 1961		October 1961		November 1961		December 1961	
	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)
1					0950:19	47.3	1250:20	54.4	0351:04	53.9		
2	0850:20	55.7			0950:49	45.2			0851:33	56.5		
3	1250:14	52.8			1251:31	56.3			1151:11	56.3		
4			1050:47	53.7			1251:05	53.4	1150:20	64.5		
5			1050:09	52.5	1250:15	54.2	0850:14	53.3	0951 04	70.0		
6	0951:33	36.0	1051:49	45.9	1250:10	47.9			1250:49	73.4	1150:33	41.0
7	1251:08	49.1			0851:00	59.4			1251:46	81.0	1151:46	49.8
8			1951:57	45.3	1150:45	57.8	0950:35	79.2	0950:40	78.3	1151:55	60.9
9			1150:08	62.0	1151:05	57.2			0850:08	93.9	1051:24	53.7
10	1250:12	53.1					1251:52	68.3	1251:10	79.7	0950:20	56.1
11			1250:57	63.7			0750:12	60.8	0850:36	70.8	1150:20	68.5
12	1350:27	52.9			1050:54	97.2	1251:13	55.8	0951:18	79.0		
13	1251:35	51.5			1151:42	71.1			1151:52	72.2		
14			1050:32	53.0	1151:29	76.6	1250:08	75.9				
15	0950:40	28.7			1251:53	76.2	0851:39	82.6	0751:45	62.5		
16					1251:58	61.9	1050:38	87.7	1251:14	66.7		
17	1151:56	34.7							1150:36	70.1		
18			1252:02	60.3	0850:16	66.1						
19			1150:20	67.3					1251:88	64.5		
20	1150:52	45.2			0950:10	67.1			1252:05	63.8		
21			1250:27	54.0	1050:29	69.2			1051:05	52.8		
22	1150:28	37.3			1151:50	74.8						
23			1250:54	56.2	1050:47	70.5					2050:50	49.6
24	1151:09	45.8	1250:11	52.7	1150:50	60.7	1251:56	69.1				
25			1150:09	65.7	1250:19	77.1	1151:05	77.6				
26			1150:33	41.3	0850:40	61.5						
27	1051:11	44.3					1050:43	77.9				
28	1050:40	29.0			1250:26	49.0	1150:50	57.6				
29	1151:25	35.9			1250:54	61.7					0450:35	92.0
30	1150:45	50.9	1350:40	69.0							1550:53	60.8
31	1250:59	53.8	1150:10	64.2			1251:27	51.6				

TABLE 1b. WHISTLER DISPERSION AT 5.0 kc

Station:	Seattle (53.6° N Geomagnetic)								Logan (49.4° N Geomagnetic)		Seattle	
	July 1961		August 1961		September 1961		October 1961		November 1961		December 1961	
Date	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)	Universal Time	Dispersion ($sec^{1/2}$)
1							1250:19	55.6	1051:09	54.0		
2	0850:21	57.7							1951:29	69.9		
3	1250:10	95.5							0850:31	67.9		
4			1050:46	67.0			1251:05	54.6				
5							1050:47	55.2				
6			1451:20	61.6					2250:12	76.2		
7									0851:07	79.3		
8			1551:52	83.8	1150:45	60.2	1251:05	73.1	0450:54	72.4		
9					1151:05	70.3			0850:07	90.8		
10							1250:28	88.6	1651:56	86.9		
11							2350:58	95.5	0850:36	85.3		
12	1350:46	97.2			0951:31	99.7						
14									1951:09	72.2		
15	1151:34	85.8			1251:50	84.1	0950:21	92.4	2050:09	82.2		
16									0050:48	78.9		
17									1251:39	72.0		
18			1250:59	72.4			1351:45	82.4	1251:10	86.3		
19			1051:17	62.9	1250:37	76.6			1251:19	77.1		
20	1050:58	47.1							0350:30	72.3		
21	1150:28	55.9	1150:57	53.2	1050:22	91.7			0450:48	66.7		
22	1151:09	42.6									0850:12	121.5
23					1050:40	79.1	1151:27	73.7				
24					1150:50	85.6						
25	1250:37	85.0			1251:25	93.5			1250:20	53.7		
28	1050:40	62.9										
29							1250:15	65.0	0852:02	86.5	0450:31	95.0
30			1250:21	78.3							0850:35	104.9
31			1150:06	68.1			0950:11	53.0				

TABLE 2a. FREQUENCY AND TRAVEL TIME AT THE WHISTLER NOSE

Station: Stanford (43.7° N Geomagnetic)

Date 1961	Universal Time	Nose Frequency (kc)	90% f_n Error +	90% f_n Error -	Nose Travel Time (sec)	90% t_n Error -	90% t_n Error +	Actual Nose
Jul								
7	1251:08	32.6	1.6	1.5	0.395	0.015	0.011	
Aug								
4	1050:47	26.1	7.6	4.2	0.393	0.047	0.030	
		21.9	11.6	5.3	.531	.106	.071	
5	1050:09	32.6	16.0	7.5	.413	.079	.050	
9	1150:08	37.1	10.0	6.1	.414	.050	.033	
18	1252:02	45.6	14.2	8.2	.322	.047	.030	
		32.1	5.3	3.7	.423	.035	.022	
		21.0	1.1	1.1	.715	.028	.022	
		16.8	2.8	2.0	.882	.059	.043	
19	1150:20	34.9	6.6	4.5	.412	.040	.025	
24	1250:11	34.8	19.8	8.7	.407	.085	.054	
31	1150:10	33.6	12.6	5.6	.285	.049	.029	
Sep								
2	0950:49	42.8	12.3	7.3	0.302	0.044	0.027	
15	1251:53	19.6	5.1	3.2	.686	.076	.057	
16	1251:58	25.9	6.5	4.2	.478	.054	.037	
		23.4	5.2	3.3	.551	.051	.035	
20	0950:10	37.3	15.9	8.2	.479	.084	.056	
23	1050:47	39.7	19.9	9.3	.406	.080	.051	
25	1250:19	21.3	2.4	1.9	.673	.035	.026	
26	0850:40	35.5	14.9	7.6	.443	.074	.049	
28	0950:31	36.1	3.0	3.0	.389	.022	.014	

Date 1961	Universal Time	Nose Frequency (kc)	90% f_n Error +	90% f_n Error -	Nose Travel Time (sec)	90% t_n Error -	90% t_n Error +	Actual Nose
Oct								
4	1251:05	25.4	6.1	4.1	0.449	0.050	0.035	
5	0850:18	32.6	9.1	5.5	.400	.051	.034	
10	1251:52	30.1	5.3	3.8	.460	.039	.025	
24	1250:16	23.2	4.6	3.1	.608	.054	.038	
31	1251:27	29.8	2.1	2.1	.363	.017	.012	
		26.5	4.4	3.2	.417	.035	.022	
Nov								
1	0351:04	31.6	8.4	4.7	0.387	0.048	0.031	
2	0850:27	24.1	4.0	2.9	.495	.038	.025	
3	1151:11	29.1	7.0	4.4	.468	.051	.034	
4	1150:20	25.4	6.1	4.1	.515	.054	.037	
9	0950:12	18.2	3.1	2.5	.690	.057	.040	
10	1251:10	12.8	1.3	1.0	1.019	.043	.036	
11	0850:36	5.3	0.2	0.2	1.462	.080	.080	x
		5.0	0.3	0.3	1.588	.080	.080	x
19	1251:28	26.1	6.5	4.2	0.485	.052	.037	
Dec								
8	1151:55	30.0	7.5	4.8	0.440	0.049	0.032	
23	2050:52	27.1	8.1	4.8	.396	.069	.045	
29	0450:35	14.7	1.8	1.5	.824	.052	.038	

TABLE 2b. FREQUENCY AND TRAVEL TIME AT THE WHISTLER NOSE

Date 1961	Universal Time	Nose Frequency (kc)	90% f_n Error +	90% f_n Error -	Nose Travel Time (sec)	90% t_n Error -	90% t_n Error +	Actual Nose
Station: Seattle (53.6° N Geomagnetic)								
Jul								
3	1250:16	18.3	3.5	2.5	0.601	0.067	0.035	
		8.7	0.2	0.2	1.378	.015	.015	x
5	0150:06	25.2	8.2	5.5	0.647	.085	.061	
		8.5	0.6	0.5	1.237	.028	.027	
16	0950:10	10.6	1.0	1.0	0.785	.016	.016	x
20	1050:58	29.4	5.1	3.5	.375	.034	.021	
	1051:52	8.0	0.2	0.2	.667	.015	.015	x
		7.7	0.2	0.2	.688	.015	.015	x
		6.2	0.1	0.1	.773	.015	.015	x
21	1150:28	10.4	0.7	0.6	.774	.022	.018	
22	1151:09	32.2	12.6	3.9	.383	.062	.040	
		11.9	0.2	0.2	.412	.015	.015	x
Aug								
6	1451:20	10.6	0.7	0.7	0.756	0.015	0.015	x
8	1551:52	13.9	2.6	1.8	1.081	.090	.065	
18	1151:11	7.0	0.1	0.1	1.646	.015	.015	x
30	1250:21	13.9	0.6	0.6	0.888	.015	.015	x
31	1150:06	12.2	0.8	0.8	0.862	.024	.025	
Sep								
14	0850:54	11.1	0.2	0.2	1.238	0.100	0.100	x
		9.5	0.1	0.1	1.338	.100	.100	x
15	1251:50	20.9	3.5	2.5	0.680	.042	.034	
19	0850:14	7.9	0.2	0.2	0.953	.052	.052	x
21	1050:22	8.8	0.3	0.3	1.275	.015	.015	x
		8.0	0.3	0.3	1.383	.015	.015	x
		7.6	0.3	0.3	1.431	.015	.015	x
24	1150:50	19.0	2.0	2.0	0.881	.042	.042	x
		10.1	0.3	0.3	1.166	.015	.015	x
		9.9	0.2	0.2	1.211	.015	.015	x
25	1251:24	13.8	1.4	1.2	1.087	.044	.039	

Date 1961	Universal Time	Nose Frequency (kc)	90% f_n Error +	90% f_n Error -	Nose Travel Time (sec)	90% t_n Error -	90% t_n Error +	Actual Nose
Seattle								
Oct								
1	1250:19	19.6	5.1	3.2	0.353	0.048	0.031	
10	1250:58	11.6	0.6	0.6	0.900	0.015	0.015	x
		9.0	0.4	0.4	1.095	.015	.015	x
		8.2	0.4	0.4	1.200	.015	.015	x
11	2350:58	16.3	2.9	2.1	0.806	.064	.046	
		14.1	1.0	1.0	0.925	.015	.015	x
		8.5	0.3	0.3	1.344	.015	.015	x
		5.2	0.3	0.3	1.908	.015	.015	x
	2351:19	39.7	14.9	7.9	0.456	.071	.047	
31	1150:06	12.2			0.862			
Station: Logan (49.4° N Geomagnetic)								
Nov								
1	1051:09	34.7	8.7	5.6	0.397	0.046	0.030	
2	1951:29	16.6	1.9	1.5	.744	.039	.029	
3	0850:31	29.6	6.8	4.4	.429	.046	.030	
		15.5	2.6	1.9	.815	.058	.039	
6	2250:12	19.9	2.3	1.8	.754	.039	.029	
		18.5	2.3	1.9	.811	.043	.033	
7	0851:07	34.7	8.0	4.5	.566	.057	.040	
8	0450:54	26.6	6.7	4.4	.608	.065	.047	
		24.7	4.0	3.2	.699	.048	.034	
11	0850:36	21.1	2.3	0.9	.693	.035	.026	
		18.5	1.4	1.4	.763	.030	.025	
		16.8	1.2	1.0	.890	.022	.018	
		5.5	0.2	0.2	1.385	.015	.015	x
		5.0	0.2	0.2	1.448	.015	.015	x
		4.9	0.2	0.2	1.512	.015	.015	x
		4.3	0.2	0.2	2.406	.015	.015	x
		4.0	0.2	0.2	2.451	.015	.015	x
18	1250:55	18.8	1.5	1.5	0.833	.032	.025	
21	0850:44	20.4	4.7	3.1	0.710	.069	.051	
Seattle								
Dec								
22	0850:12	12.0	0.8	0.8	1.423	0.040	0.030	

III. FIXED-FREQUENCY-ECHO DATA ANALYSIS

A. PHOTOANALYSIS

The clipped output signal of a narrowband (200 cps) VLF receiver is recorded for subsequent analysis at Stanford. The analysis system produces continuous photographic records of an oscilloscope trace which is intensity modulated by the signal on the magnetic tape. The process is very similar to picture reproduction in a television set; the moving trace provides the horizontal scan and the moving film provides the vertical scan. One complete horizontal sweep occurs for each ground pulse and one complete vertical scan occurs for each recording schedule. The sweep of the oscilloscope is triggered by the ground pulse, which produces an intense vertical bar on the left edge of the film record. Echoes, if present, also produce an intense vertical bar which is similar to the pulses but displaced from the ground pulse by an amount determined by the echo travel time. The photoanalysis system is described in more detail in Refs. 1 and 6.

B. SCALING OF THE PHOTOGRAPHIC RECORDS

1. Measurement of Echo Travel Time

The film is placed in a film reader and magnified by a factor of 20 to 25. The magnification is adjusted to give an integral number of horizontal sweeps per unit vertical-scale distance. At first it is assumed that the horizontal sweep rate is linear, in order to establish a linear relationship between horizontal distance and the time interval after a ground pulse. This relationship is found by dividing the interval between ground pulses by the horizontal width of the photographic record.

Once echoes are recognized on a given record, the echo travel time can be found by measuring the horizontal distance from the leading edge of the ground pulse to the leading edge of the echo and using the time-distance relationship to convert to time. Two measurements, minimum and maximum, of echo travel time are usually made, since the travel time is often observed to vary over a 4-min period. Other quantities scaled include the duration of both the ground pulse and the echo.

All measurements must be corrected for nonlinearity of the horizontal sweep and for propagation time of the ground pulse to the

receiver. The corrected data are then compiled on an appropriate data sheet. The data sheet also includes notes on interesting features such as echo fading and irregular echo structure.

2. Activity Index

An index of echo activity (see Table 3) is determined by dividing the total number of echoes by the total number of ground pulses per run. Since the period between pulses is fixed, the number of pulses can be determined by measuring the length of the run. The number of echoes is estimated as closely as possible.

3. Quality of Measurement

A number indicating the accuracy of results is assigned to each record and is listed in the "Quality of Measurement" (QM) column in Table 3. These numbers, which may be considered a measure of echo resolution, range from 1 to 4, with 4 corresponding to the highest accuracy. Errors range from about 1/10 sec to less than 1/100 sec. A dash in the QM column indicates uncertainty as to whether the measurements represent bona-fide echoes.

C. TABULAR DATA ON ECHO TRAVEL TIMES

The travel times of two-hop echoes resulting from pulse transmissions at 18.6 kc are listed in Table 3. The transmitter is NPG at Jim Creek, Washington (54.1° N geomagnetic), and the observations are made at Stanford. The date and universal time of observation are indicated, extending from 1 November to 31 December 1961. The travel times listed are the corrected minimum and maximum delays measured from the leading edge of the ground pulse to the leading edge of the echo.

Omission of a recording hour in Table 3 signifies that no echoes were detected during the run in question.

TABLE 3a. ECHO TRAVEL TIME OF PULSE TRANSMISSIONS AT 18.6 kc

Station: Stanford (43.7° N Geomagnetic)

Date 1961	UT	Activity Index	Travel Time (sec)	QM*
11-1	0240	0.76	0.89	1
	0340	0.58	0.81-0.87	1
	0440	0.63	0.40	1
			0.85	1
	0840	0.51	0.81-0.87	1
	1040	0.79	0.81-0.85	1
	1140	0.58	0.79-0.83	2
	1240	0.84	0.80-0.83	2
	1340	0.76	0.84-0.89	1
	1440	0.53	0.82-0.86	1
11-2	0740	0.42	0.85	1
	1140	0.55	0.83	1
	1240	0.75	0.83	1
	1340	0.83	0.86-0.94	1
	1440	0.67	0.80-0.84	1
11-3	0140	0.25	1.00	1
	0240	0.93	0.97-1.02	2
	0340	0.82	0.94-1.02	1
	0440	0.85	0.50	1
			0.95-1.02	1
	0540	0.93	0.90-1.00	1
	0740	0.70	0.89-1.00	1
	0840	0.79	0.89-1.00	1
	0940	0.86	0.85-0.98	1
	1040	0.79	0.84-0.95	1
	1140	0.86	0.87-0.93	1
	1340	0.93	0.85-0.93	1
11-4	0240	0.55	0.98-1.05	1
	0340	0.52	0.96-1.03	1
	0440	0.45	0.97	1
	0540	0.58	0.98	1
	0640	0.63	0.91-1.06	1
	0740	0.62	0.99	1
	0840	0.82	0.90-0.98	1
	0940	0.56	0.89-0.97	1
	1040	0.44	0.89-0.96	1
	1140	0.66	0.89-0.97	1
	1340	0.50	0.89-0.95	1
11-5	0240	0.50	1.10-1.19	1
	0340	0.69	1.12-1.21	1
	0540	1.00	1.00-1.12	1
	0640	1.00	0.89-1.09	1
	0840	0.83	0.94-1.05	1
	1040	0.30	0.95	-

Date 1961	UT	Activity Index	Travel Time (sec)	QM
11-6	0140	0.43	1.11	1
	0240	0.92	0.98-1.11	1
	0340	0.75	0.90	1
	0440	0.89	0.87-1.06	1
	0540	0.85	0.86-1.02	1
	0640	0.77	0.87-1.00	1
	0740	0.74	0.50	1
			1.00	1
	0940	0.54	0.93	-
	1040	0.46	0.98	1
	1140	0.72	1.02	1
	1240	0.71	0.97-1.05	1
	1340	0.25	0.97	-
11-7	0340	0.20	1.30	1
	0440	0.65	1.24-1.32	1
	0540	0.82	1.22-1.29	-
11-9	0240	0.45	0.92-1.03	1
	0340	0.37	0.93-1.11	1
11-12	0140	0.15	1.17-1.09	1
	0240	0.70	0.50	1
			1.07-1.19	1
	0340	0.89	0.96-0.98	1
11-13	0240	0.25	1.05	1
	0340	0.45	1.05	1
	0440	0.35	1.08	1
	0540	0.30	1.07	1
	0640	0.15	1.05	1
	0740	0.65	1.08	1
	0840	0.80	1.09	1
	1040	0.60	1.17	1
	1140	0.80	1.16	1
	1240	0.80	1.15	1
	1340	0.75	1.17	1
11-14	0340	0.30	1.40	1
	0440	0.15	1.40	1
	1140	0.30	1.20	1
	1340	0.40	1.18	1
11-15	0140	0.91	1.10-1.18	1
	0240	1.00	1.14	1
	0440	0.80	1.13	1
	0540	0.85	1.12	1
	1240	0.50	1.00	1
	1340	0.30	1.00	1
	1440	0.50	1.00	1

Date 1961	UT	Activity Index	Travel Time (sec)	QM
11-16	0340	0.51	0.99-1.14	1
	0440	0.96	1.06-1.18	2
	0540	1.00	1.06-1.14	2
	0640	1.00	1.06-1.14	2
	0740	1.00	1.06-1.14	1
	0840	0.94	1.06-1.12	1
	0940	1.00	1.06-1.13	1
	1040	0.91	1.05-1.11	1
11-17	0640	0.90	1.01-1.12	1
11-18	0540	0.30	1.20	1
	0740	0.28	1.06	1
	0840	0.18	1.04	1
11-19	0840	0.15	1.00	1
	1040	1.00	0.99-1.08	1
	1140	1.00	0.95-1.08	1
	1340	0.78	0.95-1.06	1
11-20	0240	0.70	0.94-1.02	1
	0340	0.54	0.92-0.98	1
11-21	0140	0.94	0.82-0.98	1
	0240	0.22	0.94	1
	1040	0.16	0.78	1
	1140	0.50	0.75-0.82	1
11-22	(No recording)			
12-2	0240	0.40	0.45	1
	0340	0.97	0.59-0.78	1
	0440	0.90	0.57-0.72	1
	0540	1.00	0.47-0.67	2
	0640	1.00	0.47-0.65	3
	0740	1.00	0.47-0.65	3
	0840	1.00	0.44-0.66	3
	0940	1.00	0.40-0.68	3
	1040	1.00	0.47-0.68	2
	1140	0.97	0.41-0.66	1
12-4	1240	0.40	0.75	1
	1340	0.85	0.75	1
12-6	0140	0.64	0.83	1
	0240	1.00	0.67-0.91	2
	0340	0.95	0.72-0.87	2
	0440	0.89	0.72-0.82	2
			1.05	2
			1.50	2
	0640	0.89	0.70	1

*Quality of Measurement.

TABLE 3a (Cont).

Station: Stanford (43.7° N Geomagnetic)

Date 1961	UT	Activity Index	Travel Time (sec)	QM*
12-6 Cont	0740	0.36	0.72	1
	0800	0.82	0.74	2
		0.82	1.07	2
	0805	0.60	0.74	2
		0.85	1.09	2
	0810	0.75	0.71	2
		0.75	1.09	2
	0815	0.60	0.71	2
		0.40	1.12	2
	0820	0.50	0.72	1
		0.30	1.10	1
	0825	0.65	0.72	1
		0.30	1.12	1
	0830	0.40	0.68	1
		0.20	1.08	1
	0835	0.30	0.65	1
		0.10	1.03	1
	0940	0.10	0.75	1
		0.20	1.07	1
	1040	0.30	0.75	1
		0.15	1.07	1
	1140	0.40	0.70	1
		0.25	1.05	1
	1340	0.30	0.75	1
		0.10	1.10	1
	1440	0.50	0.75	1
		0.40	1.15	1
12-7	0540	0.75	0.78	1
			0.95	1

Date 1961	UT	Activity Index	Travel Time (sec)	QM
12-8	0440	0.10	0.58	1
		0.10	0.93	1
	0540	0.20	0.58	1
		0.60	0.93	1
	0640	0.10	0.65	1
		0.10	0.95	1
	1240	0.85	0.92	2
	1340	0.45	0.74	1
	1440	0.20	0.90	1
12-9	0240	0.32	0.88	1
	0340	0.84	0.80	1
	0440	0.68	0.82	1
	0540	1.00	0.80	2
	0740	0.77	0.88	1
	0840	0.59	0.88	1
			1.05	1
	0940	0.68	0.90	1
	1040	0.55	0.88	1
	1140	0.78	0.84	1
	1440	0.20	1.05	1
12-10	0440	0.76	0.91	2
	0540	0.92	0.93	1
	0640	0.75	0.84	2
		0.75	1.10	2
	0740	0.91	0.84	2
	0840	0.95	0.80-0.92	2
	0940	0.91	0.78-0.90	3
	1040	0.81	0.78	3
	1140	0.76	0.81	2
	1240	0.83	1.10	3
			0.81	3
	1340	0.86	0.87	2

Date 1961	UT	Activity Index	Travel Time (sec)	QM
12-11	0140	0.77	0.98	1
	0440	0.77	0.80	1
	0540	0.82	0.78	2
			1.10	2
	0640	0.55	0.74	1
			0.98	1
	1340	0.35	0.89	1
		0.36	1.12	1
	1440	0.40	0.90	2
	1540	0.57	1.15	1
12-13	0440	0.30	1.10	1
12-14	0240	0.24	0.95	1
	0340	0.84	0.88	1
	0440	0.87	0.84	1
	0540	0.30	0.79-0.89	1
12-15	0140	0.75	0.84-0.93	1
	0240	0.40	0.80	1
12-16	0040	0.25	1.00	1
	0140	0.60	0.75-1.00	1
	0240	0.15	1.00	1
12-21	0440	0.25	0.65-0.80	1
	0540	0.82	0.67-0.78	1
12-25	0240	0.64	0.85	1
12-28	0140	0.60	1.00	1
	0240	0.70	1.00	1
	1540	0.70	1.00	1
12-29	0540	0.10	1.00	1
	0640	0.40	1.00	1
12-30	0140	0.60	0.81	1
	0340	0.30	0.80	1

*Quality of Measurement.

REFERENCES

1. D. L. Carpenter and G. B. Carpenter, "Data Summary: Whistler-Mode Propagation," Rept. SEL-62-001, Stanford Electronics Laboratories, Stanford, Calif., 12 Jan 1962.
2. R. A. Helliwell, "Low Frequency Propagation Studies, Part I: Whistlers and Related Phenomena," Final Report, Contract AF19(603)-795, AFCRC-TR-56-189, ASTIA Document AD110184, June 15, 1953 to September 30, 1956 (revised, 28 May 1956).
3. R. L. Smith, J. H. Crary, and W. T. Kreiss, "IGY Instruction Manual for Automatic Whistler Recorders," Prepared under NSF Grant Y-6-10/20, Stanford Electronics Laboratories, Stanford, Calif., 1 Jan 1958.
4. R. A. Helliwell and D. L. Carpenter, "Whistlers-West IGY-IGC Synoptic Program," Prepared under NSF Grant IGY 6.10/20 and G-8839, Stanford Electronics Laboratories, Stanford, Calif., 20 Mar 1961.
5. D. L. Carpenter, "Electron-Density Variations in the Magnetosphere Deduced from Whistler Data," *J. Geophys. Res., 67*, 9 Aug 1962, pp. 3345-3360.
6. R. A. Helliwell, J. Katsufrakis, and G. B. Carpenter, "Whistler-Mode Propagation Studies using Navy VLF Transmitters," Rept. SEL-62-035, Stanford Electronics Laboratories, Stanford, Calif., Mar 1962.
7. D. L. Carpenter, "Identification of Whistler Sources on Visual Records and a Method of Routine Whistler Analysis," TR No. 5, Contract AF18(603)-126, Stanford Electronics Laboratories, Stanford, Calif., 15 Mar 1960.
8. R. L. Smith and D. L. Carpenter, "Extension of Nose Whistler Analysis," *J. Geophys. Res., 66*, Aug 1961, pp. 2582-2586.
9. R. L. Smith, "The Use of Nose Whistlers in the Study of the Outer Ionosphere," TR No. 6, Contract AF18(603)-126, Stanford Electronics Laboratories, Stanford, Calif., 11 Jul 1960.
10. D. L. Carpenter, "The Magnetosphere During Magnetic Storms; A Whistler Analysis," Rept. SEL-62-059 (TR No. 12), Stanford Electronics Laboratories, Stanford, Calif., Jun 1962.

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